

## **CWRF 15-Day Multi-Physics Ensemble Hindcasts**

We have used NCEP Reanalysis 2 (R2) data to conduct 15-day ensemble hindcasts from April 1, 2002 to September 30, 2002. For each day, the hindcast ensemble includes 75 realizations that consist of 15 different initial conditions multiplied by 5 distinct model configurations of alternative physics representations. The physics configurations include a combination of different numerical schemes for cloud microphysics and cumulus convection, representing grid-resolved and subgrid-parameterized precipitation. The main purpose of this experiment is to determine the reliability of CWRF short to medium term weather forecast and subsequently provide credible ensemble climate forcings of key variables, including precipitation, soil moisture, surface temperature, evapotranspiration, surface radiation, for the irrigation model to establish an effective drought decision support system. Below we evaluate the CWRF hindcasts, comparing the ensemble mean with observations for model skill and depicting ensemble spread for forecast uncertainty, both of which are required by the irrigation model.

Figure 1 shows the ensemble mean and deviation for daily minimum and maximum surface air (2m) temperature averaged during May-June-July-August (MJJA). The low temperature over the northern Rockies and high temperature over Texas and southern states are realistically simulated by CWRF. The CWRF downscaling result, for both daily minimum and maximum temperature, is a significant improvement over the driving R2 product (not shown) due to model resolution refinement and physics representation advances. The spread among the ensemble members is much larger for daily maximum than minimum temperature. This indicates that daytime temperature is more sensitive to cloud microphysics and cumulus convection schemes as well as initializations.

Figure 2 illustrates monthly mean precipitation from May to August in 2002, including ensemble mean and standard deviation among the 75 realizations. The model successfully captures the main rain bands over the Great Plains in May, Florida and the Northeast in June, the Gulf of Mexico in July and the east coastal States in August. Again, they are significantly better than the driving R2 product indicating the skill enhancement from the CWRF downscaling. The major forecast uncertainty, as measured by deviation across the ensemble

members, is centered over the Great Plains in May, while spreads over broader areas, especially along the southern and eastern coastal States, as convections become more active from June to August. In general, the geographic distributions of deviation correspond well to the ensemble means, except for large values over the Great Plains in August

Figure 3 illustrates the daily evolutions of the ensemble mean and deviation for precipitation averaged over 8 key regions. The added values from CWRP tend to be more obvious in July and August. During this period, the RII overestimates precipitation over the Midwest, Southeast and Coast States, and underestimates it over North American monsoon region; while CWRP reduces the positive/negative biases significantly. For the forecast uncertainty, CWRP has very small spread across the ensemble members over the Cascade and North Rockies regions. This is mainly because the predominance of precipitation by the orographic lifting of incoming westerly flow makes the model insensitive to cloud microphysics and cumulus convection schemes. In contrast, all other regions exhibit large deviations, significantly enhanced during July and August, especially over the Southeast and the North American monsoon region.

Figure 4 depicts the CWRP simulated ensemble mean and deviation geographic distributions for the top 0.1m soil moisture, 1m soil moisture, downward shortwave radiation and evapotranspiration (ET) averaged during May-August. The spatial pattern for the ET ensemble mean closely resembles that for top 1m soil moisture, suggesting the strong coupled relationship between the two during summer. However, the distribution of their deviations among the ensemble members are opposite, with maximum centers over Texas and the southwest US for ET while small values for top 1m soil moisture. This is likely because soil moisture is pretty wet and sufficient for local ET over the eastern U.S., irrespective of which cloud microphysics and cumulus convection schemes used. In contrast, soil moisture is very dry over the Southwest, where local ET critically depends on available precipitation (in the absence of irrigation) that is sensitive to the representing schemes. The soil moisture deviation is largely enhanced from top 1m to 0.1m over the Gulf and southeast coastal States, indicating the strong sensitivity of precipitation schemes on surface soil conditions.

The work is done by Xin-Zhong Liang (Co-PI; email: [xliang@illinois.edu](mailto:xliang@illinois.edu), phone: 217-244-6864) and Xing Yuan (email: [xingyuan@illinois.edu](mailto:xingyuan@illinois.edu), phone: 217-244-4799).

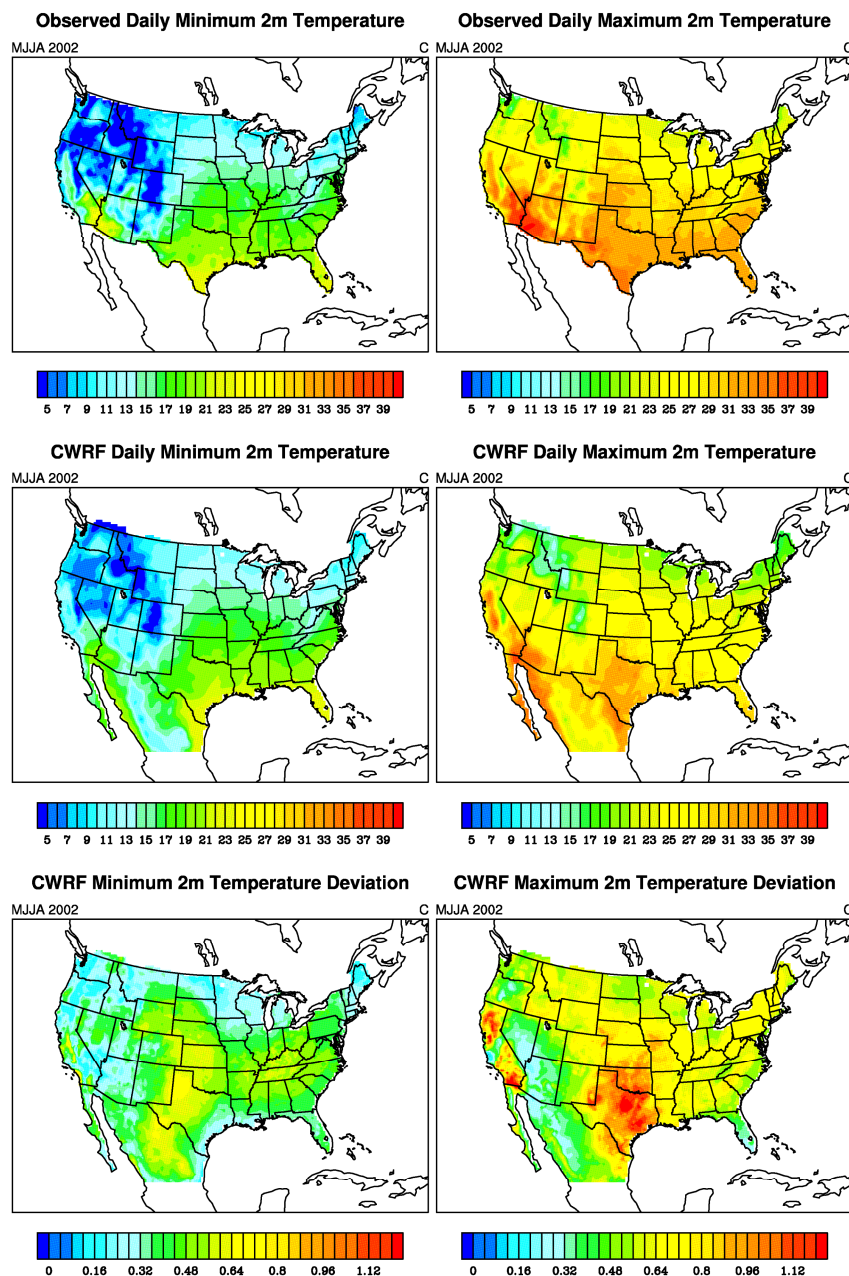


Figure 1. Observed and CWRf simulated ensemble mean and deviation of daily minimum and maximum surface air (2m) temperature [ $^{\circ}\text{C}$ ] averaged during May-June-July-August of 2002.

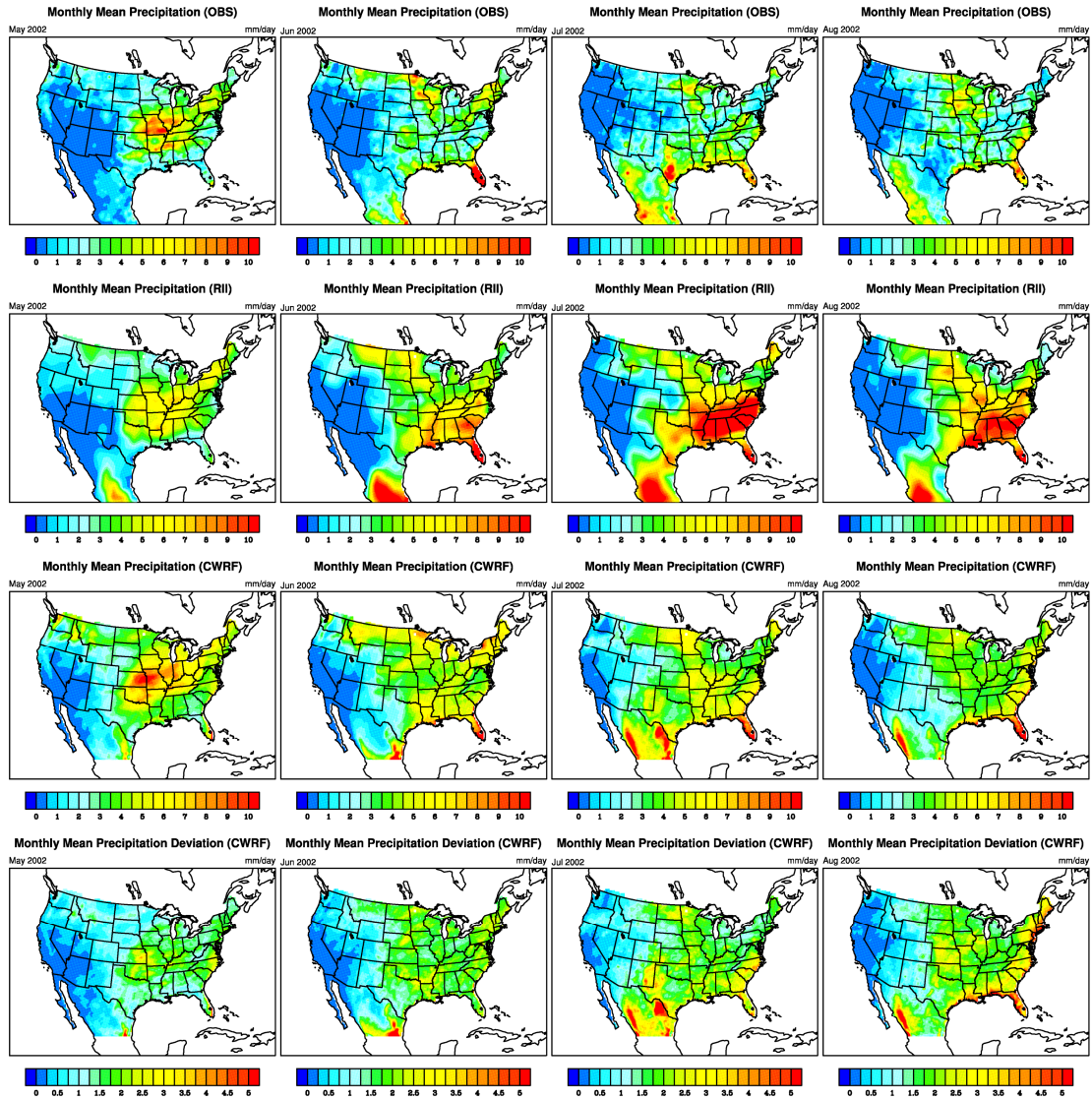


Figure 2. Observed, RII simulated, and CWRf downscaled ensemble monthly mean distributions of precipitation (mm/day) from May to August, 2002. Shown also at the bottom are the CWRf ensemble deviations over 75 realizations.

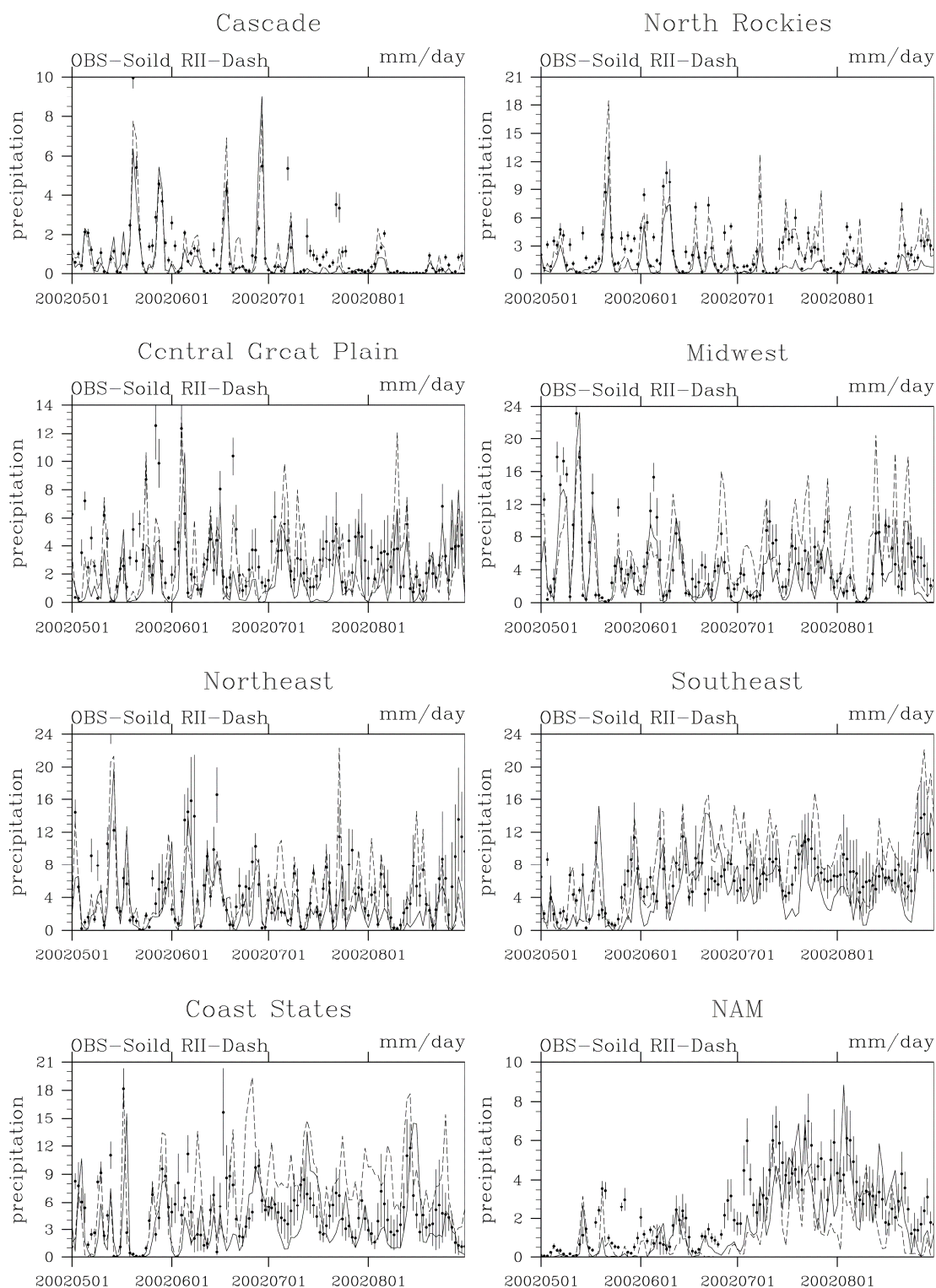


Figure 3. Daily evolutions of the CWRF simulated ensemble mean (*dotted*) and deviation (*error bar*) of precipitation (mm/day) averaged over 8 key regions, as compared with observations (*solid*) and RII products (*dashed*).

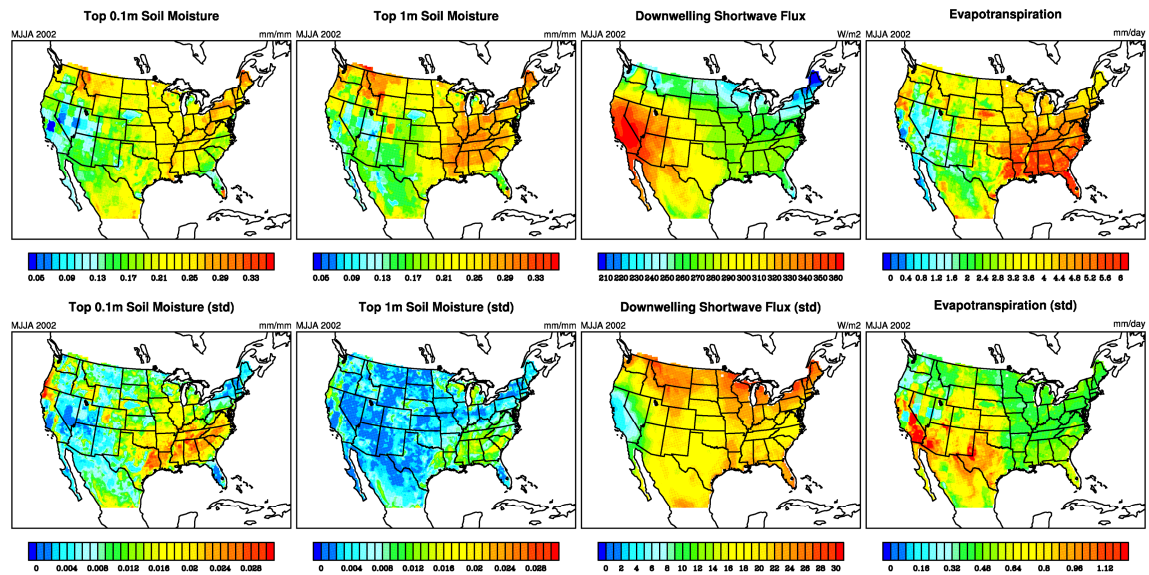


Figure 4. CWRf simulated ensemble mean (*top*) and deviation (*bottom*) for the top 0.1m soil moisture (mm/mm), top 1m soil moisture (mm), downward shortwave radiation (W/m<sup>2</sup>) and evapotranspiration (mm/day) averaged during May-June-July-August of 2002.